AN APPROACH TO THE DESIGN OF A UNIVERSITY COMPUTER CENTER IN THE BEGINNING OF THE 1970'S

by
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"Thereupon those (blind men) who had been presented with the head answered, 'Sire, an elephant is like a pot'. And those who had observed an ear only replied, 'An elephant is like a winnowing-basket' . . . . . Then they began to quarrel."

....Udana, Section 5, Chapter 4 (*)

(*) The Bible Of The World, pp. 277-279. Viking Press, New York, 1939.

ABOUT COMPUTERS.....

The electronic computer may have a more beneficial potential for the human race than any other invention in history.

Dr. Rader
Vice President, General Electric

When these new machines (computers) realize their potential there will be a social effect of unbelievable proportions. This impact on society is still to come.

J. Diebold
Chairman of the Diebold Group

The computer that lacks an ability to communicate with the outside world is in danger of remaining an isolated marvel mumbling to itself in the air-conditioned seclusion of its company data-processing room.

R. M. Bloch
Vice President, Honeywell

One of today's computers can make more calculation in one hour than a Yankee stadium full of scientists could make in a man's life. Some of the more sophisticated machines can multiply 500,000 ten digit numbers in one second. Even if no further advances were made in computer technology some scientists maintain, the computer has provided enough work and opportunities for a man for another thousand years.

Time Magazine (Special issue on computers)
April 2, 1965

The reprobation attached in former ages to the sin of sorcery attaches now in many minds to the speculation of modern cybernetics. The future offers us little hope for those who expect our new mechanical slaves will offer us a world in which we may rest from thinking. Help us they may but at the cost of supreme demands upon our honesty and our intelligence.

Robert Wiener

With a computer everything is reversed. If a one-year-old child can do it, the computer can't. A computer can calculate the trajectory to the moon. What it cannot do is to look upon two human faces and tell which is male, which is female, or remember what it did five years ago.

Richard Bellman

The computer represents an advance in man's thinking processes as radical as the invention of writing.

Dr. H. R. Simon

NOTE:

In order to simplify the footnotes, we use the following abbreviations:

A.C.M.	Communication of the Association for Computing Machinery 211 East 43rd Street New York 17, N.Y.
C.A.A.	Computers and Automation Berkeley Enterprises, Inc. 815 Washington Street Newtonville, Mass. 02160
C.J.	The Computer Journal The British Computer Society Finsbury Court Finsbury Pavement, London, E.C. 2
Datamation	Datamation. 1830 West Olympic Blvd. Los Angeles, Calif. 90006
D.P.M.	Data Processing Magazine 134 N. Thirteenth St. Philadelphia, Pa. 19107
D.P.F.S.E.	Data Processing for Science/Engineering American Data Processing, Inc. 22nd Floor Book Tower Detroit, Michigan 48226
D.P.F.N.	Data Processing for Management American Data Processing, Inc. 22nd Floor Book Tower Detroit, Michigan 48226
S.P.J.	Systems and Procedures Journal Systems and Procedures Association 7890 Brookside Dr. Cleveland 38, Ohio

INTRODUCTION

It can be said that milestones in the history of the physical sciences have been the discoveries of instruments of measure which have enabled scientists either to develop more intensive experiments or to analyze and to process great quantities of data in a more efficient way, often the second consequence being related to the first. For example, we can say that the microscope has opened the doors of research in the biological sciences, that the telescope created an uproar in astronomy and in physics, that, more recently, the cyclotron provided the modern scientist with a marvellous tool to look at the intimacy of the matter.

It is to be noticed that those instruments have been considered as practical tools at the beginning of their discovery, tools whose uses and efficiency were not well defined. People had to wait for a theory and a definition of a system (or systems) for which the tools were fit.

Nowadays if we want to observe the behavior of an amoeba we will just look in a catalog for one among a big choice of microscopes which will provide us with the best efficiency depending on what and how we want to perform our experiment. The components of the system, here the microscope and the experiment, are well defined and there is no main difficulty in measuring the efficiency of the system.

Today, too, science has at its disposal what can be called the biggest and most outstanding instrument man has ever created: the ELECTRONIC COMPUTER. Conceived first as a scientific instrument, the computer has spread its influence in almost all the fields of our present life and has become the most important tool of decision making for the scientist, the businessman, the militaryman.

Computers' tasks are merely focused on processing and analysis of data, but they find their applications in more than 500 areas, and these are growing every day.[1] Computers represent the most efficient tools to run such various systems as flight-test simulation, investment banking, production control, perception studies, automatic teaching, etc.

Can we extend to the computer the assertion we previously made referring to the use of a microscope in observing an amoeba and to evaluate the "performances" of such a system? That is, considering a system whose data has to be processed and whose performances have to be measured, can we look into a computer-catalog and choose the best computer fit for our measurements? Do we have a theory of computer uses at our disposal as we have theories of microscope or telescope uses? Are the components of the instrument and its implementation sufficiently settled to provide a satisfactory answer to one who wants to use them with the maximum efficiency? What are the criteria of measurement of this efficiency?

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[1] Industrial Securities Committee, A Survey And Study Of The Computer Field, Computers And Automation, Jan. 1963.

If we look at the literature of recent years[2], we see that no basic theory has been established yet and that the planners of a computer center have to be careful in making their decisions. Then is it not a paradox to say that the computer is the most efficient tool in managing[3] and that there are no well-defined rules, no well-established criteria in evaluating the performances of a computerized system?

It could be one. In fact, the computer is in its age of youth still growing since its birth some twenty years ago, and every day the computer is cracking the performance clothes some people would like to dress it with; by the time some survey or study on computer systems has been done, by the time they are published, they are outdated. Does it mean that we have to wait until our young man becomes an adult to analyze him and to compute his performances?

We would have a very narrow mind in doing that and that has not been the attitude of the managers of computer centers who have always been trying to optimize

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[2] Louis Fein, Assessing Computer Systems, D.P.F.M., Feb. 1964.

J. D. W. Janes, Measuring The Profitability Of Computer System, C.J., Jan. 1963.

R.B. Curry, The Significance of Computer Investment Decisions, C.A.A., Sept. 1962.

D.H. Brandon and F. Kirch, Performance Standards, C.A.A., July, 1964.

J.C. Richter, Organization and Management Of Large Installations, D.P.F.M., May, 1964.

[3] We consider "management" in the broad term as defined by Prof. C. W. Churchman in "The Myth Of Management," The Ethics of Large Systems, Internal Working Paper No. 37, Spaces Sciences Laboratory. Berkeley, Sept. 1965.

the uses of their computers even if they knew that the technology of tomorrow would outdate the technology of today. On the contrary, we have to look at the future and to see if some adulthood age is not in sight for computers and if we cannot find some stabilization in gauging the performances of the systems we are interested with.

After two generations, the first one being the generation of vacuum tubes, the second one being the generation of transistors, the computer is now in its third age with the thin films, micro-miniaturizated components, a generation which is predicted to stay much longer than the precedent ones and which could bring a (relative) stabilization in the concept of computer systems.

Hence the computer technology is trending toward two kinds of stabilization:

-stabilization in the prices of the components (hardware and software) of computers centers which enable the managers to think out their systems in a much cooler way than before. Connected with this idea is the fact that people are taking advantages of past experiences. For big units the marginal expenditure to increase the capacity of a center is small relatively to the improvement which is provided.

-stabilization in the technology itself the speed of light, speed that the technicians try to approach the nearest possible, being a definited limit for the improvement of performance, especially with the sequential machines.

Can we conclude that time has come for the formulation of the theory of data processing systems and that some efficient devices, which could play the similar role as PERT or CPM in controlling the efficiency of systems, have to be created now? Such a thing would release the burden of the managers of data processing systems and would spare them a lot of grey hair. We do not think that the theory can be expected soon[4], but this does not prevent us from thinking about it. That is precisely the purpose of this paper.

To accomplish this we have decided to focus on a special type of data processing system: a university computer center. With its importance in the educational field, with its impact on research, with its extensions in the outside world (we have not to forget that the place of birth of the first computers was the university campuses and that the main discoveries in the computer field have been made by university people), with its perpetual growth, the university computer center provides us with an excellent example.

Referring to what the presumptuous title of our paper could bring to a non-advised mind, we have no illusion about the value of our study (we do not forget that the technology is going much faster than our writing) and the purpose of this paper is not to give a precise definition of a university computer center in the beginning of the 1970's.

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[4]Ned Chapin, Conceptual Aids: The Needs for Them In Developing Data Processing Systems, CAA.., August, 1960.

The purpose of this paper then is to raise questions, to detect problems and finally to attempt to define a methodology which can be used in future studies to find solutions to problems which have not yet been detected but which will subsequently arise. We think that the solution of the design of a university computer center will come step by step in a discrete procedure. The aim of this paper is to awake criticism among the computer people who will read it, and from this constructive criticism to get a better knowledge of the design of a university computer center.

To achieve its goal the outline of this paper is the following:

PART I: TASKS OF A UNIVERSITY COMPUTER CENTER IN THE BEGINNING OF THE 1970'S

A. Analysis of the Present Situation.
System. Independent department. Dependent department.
Structure. People. Time. Costs.
Turnaround time.. Independency of a department. Classification of people

B. What the Future Will Be,
Needs of computer by the industry.
1. Historic of the concept of computer sciences
2. Services

PART II: THE TECHNOLOGY AND ITS CONSEQUENCES IN THE BEGINNING OF THE 1970'S

A. Evolution of People and Systems.
1. The scientist in the computer field.
Physicist. Electronics engineer. Circuit designer. Functional block designer. Computer system designer.
2. The Evolution of the concept of computer system.
Classical batch processing. Improved batch processing. Remote batch processing. On line interactive computing.

B. Time Sharing: Terminology and Prospective.

1. Terminology

   Multiprogramming. Multiprocessing Real-time processing. Interactive or on-line processing. Remote processing. Multiple access. Processor. Job dividing. Divided job processing. Program suspending. Scheduling. Production Interactive. Critical real-time

2. Prospestive of time sharing.

   Advantages. Disadvantages

   Technical, sociological, economics, problems.

PART III: MAPPING THE CONCEPT OF A UNIVERSITY COMPUTER CENTER IN THE TECHNOLOGY OF THE BEGINNING OF THE 1970's

A. The University Computer Center In The Beginning Of The 1970's: The Time Sharing System.

Justification of the time sharing system. Advices of expert people, best characteristics of a computer center, study done.

B. Methodological Recommendations for a Better Knowledge of the Present Situation and an Efficient Implementation of the Future System.

Need of a statistical bureau. Better knowledge of the concept of teaching and research. Better understanding of the needs of industry. Better knowledge of the concept of services. The technical problems. The economic problems. The sociological problems. The transition time. Simultation models.

CONCLUSION: AN EXAMPLE OF A TIME SHARING COMPUTER CENTER AND ITS COST ANALYSIS

PART I: TASKS OF A UNIVERSITY COMPUTER CENTER IN THE BEGINNING OF THE 1970'S

To provide excellent TEACHING for students, adequate facilities for RESEARCH people, and efficient SERVICES to the outside community are the three main purposes of a university campus. To determine the participation of a computer center in those tasks we can consider two points of view:

-The first one is to look at the present situation on the campus and to detect its main characteristics. From the values of those parameters and from the data obtained in the analysis of the previous years, we can plot graphs which will bring us valuable information on:

- the evolution of the computer center as it has occured the last past years;
- the trends of this situation and what can be expected in the years to come, all our hypothesis being weighted by appropriate probabilities.

This is a statistical and quite "static" approach of the problem, the second one is a more dynamic one:

- The second approach consists in analyzing the hypothesis which have been formulated concerning the conception of Teaching, Research, Services and the whole concept of the university in the beginning of the 1970's and from this analysis to foresee the impacts of those predictions on the future role of the computer center.

It is to be noticed that these two approaches cannot be disassociated and are closely inter-related, the probabilities concerning the evolution of the situation being guessed from the conception of the future, and, visa versa the estimations of the situation in the future being sustained by the analysis of known data.

Before examining those two points in detail, let us give some definition of terms we can use in the following of this paper:

SYSTEM:

> The system we are considering is a broad system including all the computer facilities, people and machinery, which can be found on the campus or which can be related in whatsoever way with the notion of computer. The computer center, the departments, the administration, the companies which sell hardware and software, are, for example, components of the systems.

INDEPENDENT DEPARTMENT:

> An independent department is a department which can do its own computing without the aid of the computer center or which does not need computer. As example, the Radiation Laboratory can be considered as an independent department. It is the only one presently but nothing prevents a department from becoming independent in the future, at least if it has enough political power to do it.

DEPENDENT DEPARTMENT:

A dependent department is a department which is not independent, that is this department needs to use the services of the computer center more or less often.

A. ANALYSIS OF THE PRESENT SITUATION

Usually to evaluate the performances of a system, the businessman or the economist has at his disposal elaborated and sophisticated theories. For example, in budgetary control, the appreciation of a situation can be made by computing some ratios as the turnover of the working capital, the ratio of liquid assets . . . in statistical analysis correlation coefficients, bias of estimators . . . are well defined tools. On the opposite, if we look at the literature of the past nine years concerning the management and the economics of data processing systems[5] we see the statistical analysis and the tentative nature of the definition of efficiency criteria which have just been undertaken[6]. Up until now no predominant parameters have been placed forward in order to characterize the features of a computer center although there have been a lot of writings on the philosophy of management of data processing systems.

In our opinion this is relevant from the fact that the technology has proceeded very fast and people have not had enough time to think of the economic structures

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[5] C.A.A., D.P.F.M., C.J., A.C.M.

[6] G.A. Garrett, Management Problems of an Aerospace Computer Center, AFIPS, Fall Joint Computer Conference, 1965.

G.K. Hutchinson, A Computer Center Simulation Project, A.C.M., Sept. 1965.

R.F. Rosin, Determining A Computer Center Environment, A.C.M., July, 1965.

W.C. Lynch, Description of a Fast Turnaround University Computing Center, A.C.M., Feb 1966.

of their systems. Hence as we have no references for what is worth being measured (also the people generally agree that the turnaround time and the number of jobs[7] are two important factors), we have to guess at what is interesting to be looked at and to define it.

We think that the statistical analysis of the following items should be done[8]:

STRUCTURE:

General organization. Equipment of computer center and departments. Hardware. Channels of communication. Frequency of changes. Services . . . etc. . .

PEOPLE:

Administration. Computer staff. Computer people (center and departments). Categories of users. Relative frequency of the users. Preferential treatments. Degree of satisfaction. Difficulties . . . etc. . .[9]

TIME:

(Useful time, idle time, lost time, routine, maintenance, service time) for the computer center and the departments. Allocation of the time of the computer center . . .[10]. Frequency of jobs in

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[7] Conversation with Prof. P. H. Morse after a seminar on the project M.A.C., Berkeley, April 18, 1966.

[8] A detailed study mainly pointed at the analysis of the users and non-users of the computer center has been done in 1962 by the Survey Research Center, U.C., Berkeley Campus. Unfortunately this study gives us only one basis of estimation and has not encompassed enough the data which enter in the items JOBS, TIME, TURNOVER principally.

[9] See reference (8) above.

[10] R. F. Rosin, ibid.

the day, the week, the year...[11]

COSTS:

Overall costs. Managing costs. Hourly costs. Rental costs. Hourly costs of an alternative source (e.g. for a department the use of the computer center for people the use of the Western Data Processing Center in Los Angeles, as examples). Programming expenses. Library costs. Maintenance costs. Training costs ...etc...[12] [13] *

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In writing this paper during a semester, we had not the authority or the time or the money at our disposal to conduct such a study, one which would require a strong preparation before being undertaken. To provide the analyst with reliable information, a statistical survey of this kind should be done at regular times: there are an infinity of graphs which pass through one point; there is only a straight line to join two points; for three points we can guess a little; for four points we begin to get interesting facts . . . A study like the study made by the Survey Research Center loses the major part of its impact if it is not followed by further studies.**

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[11] R. A. Buckingham, The Organization of a University Computing Center, C.J., 1960.

[12] G. K. Hutchinson, ibid.

[13] Louis Fein, ibid.

*The questions of costs will be detailed in Conclusion as an example of a time-sharing system.

** See footnote 8, p. 4.

We comment on some few points which need special attention:

TURNAROUND TIME:

The turnaround time is defined as the time elapsed after the user deposits a job at the computer center until the output is available to the user at the computer center. If:

t1 is the time the users deposits his job
t2 is the time the computer start to process the job
t3 is the time the computer finishes to process the job
t4 is the time the user can get his job at the computer center

waiting time to be processed	processing time	waiting time to be picked up

t1 —————— t2 —————— t3 —————— t4

the turnaround time is then $t_4 - t_1$.

As defined, the turnaround time can be a misleading parameter. For example, is it appropriate to say that two jobs have the same turnaround time when the processing times are completely different? We think that a more appropriate ratio should be defined and we suggest the following:

$$\frac{\text{Processing Time}}{\text{Turnaround Time}},$$ as this ratio can be very small (its ideal value to the user being 1) some measurement scale should have to be defined.

INDEPENDENCY OF A DEPARTMENT:

The independency of a department can be defined by the ratio:

$$\frac{\text{Number of hours used at the computer center}}{\text{Total of computer hours required}}$$

This ratio should be evaluated taking care that an hour of the machinery used at the computer center is generally far more powerful than an hour of the computer used at department.

When a department acquires a computer for its own use, this ratio falls considerably. It would be interesting to see what the tendency has been these past years. This ratio can also be computed in job quantities.

PEOPLE:

The following classification of university people has been suggested by R. F. Rosin of Yale University[14]:

- -Students in high level general programming course
- -Students in a freshman sophomore programming course
- -All other students using the Center facilities for course work
- -Faculty personnel involved in unsponsored research
- -Students involved in doctoral thesis research
- -Sponsored research project personnel
- -Computing center staff

This classification has enabled him to compute such a ratio as the percentage of jobs which reach execution, the ratio of successful translations, the percentage

[14] R. F. Rosin, _ibid_.

of I/0 errors . . . etc. . . for the different categories of users and hence to get useful results and valuable experience.*

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Hence the statistical analysis of the data processing on the campus can be the source of better knowledge and then better understanding of the numerous functions of computers and computing on the campus. From those data we could forecast some trends of the present situation, but, independently of this analysis we also can look at the predictions of the computer people concerning this future, how do they estimate the future? what is the future supposed to be? That is what we propose to study in the following.

B. WHAT THE FUTURE WILL BE

In a recent article[15] we can read:

> "Education and computers are closely allied subjects. They are closely allied because of the crying need for education about computer, and the ray of hope that computers offer to education . . . . . . An estimate of the number of people by category, in today's data processing installations of the future is as follows:

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[15] C. E. Ransom, Computers and Education: The I.B.M. Approach, a Report and an Evaluation, C.A.A., March, 1966.

* See footnote 6, p. 3: "Determining A Computer Center Environment"

	1966	1970
Top Management	40,000	75,000
Data processing managers	30,000	55,000
Systems analysts	50,000	190,000
Programmers	120,000	200,000
Operators	60,000	130,000
Totals	300,000	650,000

. . . Where are those people going to come from? . . . they will come, to the extent of over 90 percent, from the ranks of industry . . .

. . . In general, in the period 1966 to 1970, we do not expect public and private educational institutions to supply more than a few of the necessary people in the above categories. High school, college and graduates trained in graduate sciences will completely be insufficient to complete the need. . .

. . . Colleges, schools and universities should make a prodigious effort at this time to expand data processing instruction. If hundreds of thousands of people are to be trained, the regular educational institutions should join in meeting the need for education in the computer field."

This outlook of the situation, as felt by the major manufacturer of computers, International Business Machines ~~Corporation~~, brings a feeling of dissatisfaction and frustration. Dissatisfaction and frustration because it is unfortunate to see that the educational field will not be able to assume the tasks it is devoted to. But this outlook brings an appeal and an insurance too, an appeal because it invites the universities to keep on working hard in such an exciting field as computer; an insurance because it brings the security that the work of university people, educators, researchers and students have bright openings in the world outside the campus and can expect financial support for performing their jobs.

Similarly an article of "Business Week"[16], "The $5 Billion World Market For Computers" emphasizes the uproar of the computer field: "a revolution bigger than the revolution of the automobile" and the bright issues one can expect. What is the answer of the university people to these predictions?

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I. HISTORY OF THE CONCEPT OF COMPUTER SCIENCES

Although the university computer people have been aware of this shortage for a long time[17] it does not seem that a vast program of intensive training in the computer field has been settled in universities. University people have been more inclined to try to dissipate the smog which was surrounding the almighty child they had to raise. From this childhood the concept of Computer Sciences has progressively emerged. Let us look at a page of history:

1960: Conference Report on THE USE OF COMPUTER IN ENGINEERING CLASSROOM INSTRUCTION.

April 29, 30, Ann Arbor, Michigan.[18]

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[16] "The $5 Billion World Computer Market for Computers," Business Week, Feb. 19, 1966.

[17] "Experts in the field of computer sciences are in very short supply; the shortage will remain acute until more colleges train more of them." Conference of University Computing Directors, A.C.M., 1960., p. 520. We have not found data concerning this point.

[18] A.C.M., 1960., p. 522.

...."One of the problems is that the pedagogy of computer has not been yet developed properly..."

Perlis

...."Ideas of using a computer are then how you give instructions to the machine. It is a way of thinking, a whole philosophy, which is probably better taught not in terms of engineering calculations but in terms of much more common elements...."

Haming

...."So that the student can see that the computer is far more than just an arithmetic tool. The bulk of computer applications will not be arithmetic. It is clearly to be symbol manipulations...."

Haming

...."The computer can be used very early to motivate students to understand ideas in mathematics...."

Arden

...."I am opposed to any introduction of the computer in the beginning, or at any point along the way, which tends to regard the computer as a super slide rule. This is not the fundamental role which the computer is going to play in our society. It is a small section...."

Haming

...."Should this course (computer course for engineering students) be incorporated into the mathematics program?...."

Katz

...."It should be a course in engineering ...not in mathematics. People taking this course can greet it as part of engineering and the profession...."

Glennie

...."We want to teach students to recognize the structure of a problem, and to operate with it. This is what we do, or should be doing in mathematics. It should be launched in mathematics...We should be encouraging our math instructors to adopt this point of view...."

Stein

From these abstracts it is clear that there is a strong disagreement to precisely define the computer science; does it belong to the mathematics or to the physics? is it a tool, a device or symbols manipulations? It can be noticed that people as Haming already define the Computer Science as it is presently done.

1961:

In a bold essay[19] Louis Fein defines the Computer-Related Sciences or SYNNOETICS as it is in the year 1975:

> "Synnoetics is the science treating of the properties of composite systems - consisting of configuration of people, mechanisms, plant or animal organisms, and automata - whose main attribute is that its ability to invent, to create, and to reason - its "mental" power - is usually greater than the mental power of its components."

The Computer-Related Sciences department has then fully achieved its recognition in the university with its very high level qualified staff (best salaries of the university), its extensive research programs, its A.B.'s, M.A.'s, Ph. D's, and the huge influence of this department in the educational field.

1962:

Although he gives a good idea of the University Computing Center, Charles Wrigley considers the functions of the computer as a tool or device:

> "My prediction is that the electronic computer will prove to be the most versatile and influential scientific instrument so far invented and that it will play a larger role in the scientific histories of the future than even such obvious challengers as the

[19] Louis Fein, The Computer-Related Sciences (Synnoetics) at the University in the year 1975, American Scientist, June, 1961.

microscope and the telescope...To the scientist with limited time and energy, the computer means extra research assistance. Unlike its human counterparts, this assistant is indefatigable."[20]

More elaborated and more predictive are the ideas developed at the evening lectures held in celebration of M.I.T.'s Centennial Year and published in 1962.[21]

> "The impact of the digital computer upon university education, it seems to me, will stem mainly from the changes the computer will produce in intellectual activities generally. The pedagogical responsibility of the university is not to lecture or to assign problems or grade them. It is to create a situation within which most of the students will automatically learn."
>
> J. C. Licklider

> "A course in programming if it is taught properly is concerned with abstraction: the abstraction of constructing, analyzing, and describing processes...The point is not to teach the students how to use Algol, or how to program the 704. These are of little direct value. The point is to make the students construct complex processes out of simpler ones (and this is always present in programming) in the hope that the basic concepts and abilities will rub off."
>
> Perlis

> "One can say, 'All right, if mathematics is not the language for stating procedures, what is mathematics?' The answer is that mathematics is the language for stating certain classes of facts, and a fact is different from a problem; a fact is also different from a procedure. One would suppose that appropriate languages for describing procedure will contend components which have a lot in common with mathematics and which contain a certain amount of mathematics; but they will also contain other things which are yet to be developed."
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> McCarthy

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[20] Charles Wrigley, The University Computing Center, Computer Applications in the Behavorial Sciences. Prentice-Hall, 1962.

[21] The Computer in University, Computers and the World of the Future, The M.I.T. Press, 1962.

People agree on the concept of computer sciences: manipulation of abstract symbol, abstract procedures. But as the main part of the components has not been developed yet, only a general definition of what a computer science course should be is given by Prof. Perlis.

1963:

Howard E. Tompkins provides extensive listing of the activities of university computer centers throughout the country but omits the study of computer sciences education.[22]

1964:

Publication of a Panel discussion held during A.C.M.'s National Conference in Denver. Several educators present papers describing several courses which could form a basis for a computer science curriculum.[23] We can read:

"By now it seems clear that the study of the organization and structural

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[22] Computer Education, Advances in Computers, Academic Press, New York, London, 1963.

[23] A. J. Perlis, Programming of Digital Computers;
R. R. Korfhage, Logic For the Computer Sciences;
B. W. Arden, On introducing Digital Computing;
G. E. Forsythe, An Undergraduate Curriculum In Numerical Analysis;
Saul Gorn, Mechanical Languages: A Course Specification;
D. E. Muller, The Place of Logical Design and Switching Theory in the Computer Curriculum;
W. F. Atchison & J. W. Hamblem, Status of Computer Sciences Curricula in Colleges and Universities;
T. A. Keenan, Computers and Education;
All these papers can be found in A.C.M. Volume 7, April, 1964.

properties of systems, arrays of symbols and mechanical languages which find their application in the processing and communication of information is at the heart of computer science. More specifically, we can identify four topics with which the computer scientist is concerned:

1. Organization and interaction of equipment constituting an information system. The system can include both machinery and people, and its organization will be influenced by the environment in which it is embedded.

2. Development of software systems with which to control and communicate with equipment. Here is included for example mechanical languages, executive systems, systems to facilitate the reception and display of visual and aural information, etc....

3. Derivation and study of procedures and basic theories for the specification of processes. Specific topics included would be numerical analysis, list of processing procedures, heuristics and a theoretic basic for information retrieval.

4. Application of systems, software, procedures and theories of computer sciences to others disciplines. A continual awareness of potential application is a stimulus to the computer scientist as it is in the other disciplines."

T. A. Keenan

"The objectives (a sequence of courses in logic for a computer curriculum) should be to give the student a good background in all areas of logic which are now relevant to the computing sciences and those which will apparently become relevant within a few years....We should delve quickly into symbolic and algebraic logic since the computer is a symbol manipulator and since the algebra of our logic is reflected more or less directly in the design of computer software and hardware...a computer course in logical design should probably stop at the logical elements without discussing their exact physical form.

R. R. Korfhage

Among all these papers, Prof. Perlis' (Prof. Perlis seems to be the dominant advocate of computer sciences education) is particularly precise*. But in a critique from T. M. Gallie, Duke University, we can find:

> "Too few universities, I fear, have enough professors who understand all the points in Perlis' outline, and too few computers are prepared to converse in a stimulating way with a large number of students."

The main feature of this panel is that for the first time computer education has been discussed in front of a large and national hearing (The lectures given at M.I.T. had a restricted and local impact) and we can find a recognition of Computer Sciences at a high level with proposition of detailed programs.

<u>1965</u>: Report from The ACM Curriculum Committee on Computer Sciences:

After three years of intensive work the C3S Committee publishes the report of a one week session, held during the summer of 1964 at Poughkeepsie, in which it accurately defines the Computer Science Curriculum, although it does not consider the suggestions made as final but only as a point of departure.

> "Although much change has been accomplished within existing programs such as mathematics and electrical engineering, there is a sizable area which does not naturally fit into any existing field. Thus, it is now generally recognized that this area, most often called Computer Sciences, has become a distinct field of study.
> ....The Committee has chosen to direct its attention first to the student whose primary interest is in computer sciences. The Committee solicits comment and criticisms of the present report with the view of both strengthening the current recommendations and illuminating the relation between computer sciences and other fields of study.
> ....At the time of this writing, in the United States, doctorates

* See footnote 23, p. 14: "Programming of Digital Computers"

can be sought at more than 15 universities, master's degrees at more than 30, baccalaureat at least in 17 colleges, and a sizable number of other colleges and universities are presently planning considering departments of computer sciences.
...In some schools an independent department of computer science may be appropriate; in others such a department of computer sciences may not.
...The work of C3S is in its early stages. Readers of this report are encouraged to communicate their ideas, their experiences, and criticisms to the Committee.
...Finally, the present recommendations do not deal with graduate computer sciences. A committee to study graduate curriculum is in the process of formation."

A "Table for Courses For Computer Sciences Majors" and a "Catalog Description of Computer Science Courses and Prerequisites" are detailed.[23a]

****

From this historical survey we can conclude that the computer has been the rocket which has launched the man into the space of Computers Science, a new field of education for professors and students, of investigation for the scientific researcher. This field is now considered as independent from the other sciences and the scientist is evolving in it referring to the computer as a secondary tool or device.*

It is certain that this situation will considerably develop in the years to come; what can we expect from the evolution of the SERVICES that a university computer center can provide and has to provide?

[23a] ACM CURRICULUM COMMITTEE ON COMPUTER SCIENCES, "An Undergraduate Program In Computer Science - Preliminary Recommendations, A.C.M., Sept. 1965.

*A Ph.D thesis on computers can be written without any use of a computer as the Ph.D thesis of Jean Yves Leclerc, "Memory Structures for Outline Interactive Computer," Electrical Engineering Department, Berkeley, May, 1966.

2. SERVICES

Device and Tool

"It is unworthy of excellent men to lose hours like slaves in the labor of calculation," declared Leibnitz in 1671, seeking unsuccessfully to invent a mechanical calculating machine.

That was three centuries ago and now the "excellent men" have at their disposal electronic slaves who bring them a gigantic power of processing computation in a painless way which was not only conceivable at Leibnitz's time but even a few years ago. The following comment on the humanist scholar[24],

> Let us, therefore, see the computer as a means of liberation, freeing the humanist scholar from the time-consuming operations of the past, a tool rapidly providing him with proliferating resources in the form of statistics, collations, print-outs, cross-references, frequency-counts and hypothetical models upon which he may build a research of new dimensions and complexity. Viewed in this light, it is a device the potentialities and applications of which we cannot afford to ignore.

can be applied to every researcher and student of the campus using computer as an excellent device to relieve him from the tedious and frustrating task of computation.

Among the special attributes of the computer, we can quote[25]:

1. A facility for very rapid calculation, which is valuable both for simple routine operations and for more difficult and abstruse calculations.

---

[24] E. A. Bowles, The Humanities and The Computer: Some Current Research Problems, C.A.A., April, 1966.

[25] R. A. Buckingham, The Computer in University, C.J., April, 1965.

2. More generally the manipulation of symbols of all types, whether abstract (in the sense that they do not directly convey information, e.g. numbers, words) or less abstract, such as maps, pictures or patterns which do convey information.
3. An ability to analyse completely, in a reasonable time, a complex structure such as a tree or network in many dimensions.
4. Following on this, the analysis of recursive structures, perhaps involving repeated interruptions to enter a nested sequence of subroutines, some of which may be identical with routines already entered.
   (This is difficult for humans. Professor G. A. Miller of Harvard recently quoted the following sentence of nested clauses: "The film that the script that the novel that the producer whom she thanked discovered became made was applauded by the critics.")
5. The generation and analysis of large numbers of random events within a framework of restrictions appropriate to the problem being investigated.

The impact of these attributes on fields as numerical analysis, biochemistry, business administration, engineering ... has not to be emphasized. What should be emphasized is the quantitative evolution of the involvement of university people in the computer uses in order to know what we can expect in the future. But here again as basis of reference we have no statistical analysis.

The survey "Use Of A University Computer Center" done by the Survey Research Center in 1962 tells us[26]:

> This section has dealt with the future use of Center services and of the newly installed IBM 7090 computer. Only 10 per cent of

[26] "Use Of A University Computer Center", Survey Research Center, University of California, Berkeley Campus, pp 82.

> the users reported that their use of Center facilities will entirely stop, although 20 per cent thought that their use of the new computer was less than certain or probable.
>
> Among those who expressed some doubts about their use of the IBM 7090, or who were fairly sure that they would not use it at all, the two reasons most frequently cited were that the respondents were about to leave Berkeley (or had already done so), and that their use of the computer would depend on their research needs.
>
> Half of the users reported that their use of Center facilities would increase, a fourth thought it would remain about the same, and only four per cent thought it would decrease. Among those whose use will increase, the two major reasons were that a new project was getting underway or that the user was changing to new types of research, or that continuing research would increase in volume; among those whose use will decrease, the major reason was that the problem had been finished or the project was moving into the writing phase; and among those whose use of Center facilities will stop, the majority cited their leaving Berkeley as the reason.

but does not tell us how intensively the university people have used the services provided by the computer center, and such a survey has not been conducted for four years now and is outdated.

How will this situation evolve; what can we expect in the beginning of the 1970's in the uses of the computer center as services by university people? It is difficult to make a prediction[27]:

> Unless data processing development has reached an inflection point on its growth curve, and all the evidence denies this

[27] T. B. Steel and F. N. Marzocco, New Horizons for Computer Usage, D.P.F.S.E., February, 1964.

> hypothesis, there should be as much progress in data processing in the next 10 years as there was in the millennium between Gerbert and the 7094.
>
> What, then, will this brave new world of the 1970s be? Indeed, can we even hope to estimate its character rationally? An engineer would proceed with caution, carefully plotting trends and noting all the difficulties. If he were sophisticated in predictive techniques, of course, he would draw his plots on logarithmic scales, and for two, perhaps three, years his guesses would be close to the mark. Thereafter, and with increasing velocity, his view of the future would become a gross underestimate.

Nevertheless it can be said that more and more people will use the services of the computer center in the future and spend more time. The "computerization" of the campus activities will become complete. From scientific areas, this phenomena of computerization will first spread completely throughout the Humanities field[28]:

> Furthermore, within a short time, I believe a knowledge of data processing will become part of the "common baggage" of research tools and techniques required of every graduate student in the liberal arts. I am even tempted to go a step further and state that with the increasing number of courses in programming being offered at our universities the time may come when some students in the humanities may be as fluent in programming as in writing English composition. Certainly, the computer is fast becoming an important and indispensable research tool for faculty and students alike.

---

[28] E. A. Bowles, ibid.

and the picture given by Louis Fein in his essay on "Synnoetics" will not be far from reality as we see in the following examples of users of computer services:[29]

Studies in Intuition and Intellect of Synnoetic Systems - Psychology Department Patent and Precedence Searches with Computers - Law School
Computer - Aided Medical Diagnosis and Prescription for Treatment - Medical School
Synnoetic "Business Executives" - Business School
Theory of Creative Processes in the Fine Arts - Humanities Department
Theory of Error and Equipment Reliability - Engineering School
Design of Analog and Digital Computers - Engineering School
Simulation in the Behavioral Sciences - Psychology Department
Machine-Guided Taxonomy in Botany - Botany Department
The Theory of Graphs and the Organization of Automata - Mathematics Department
The Effect of Automata on the Legislative and Judicial Process - Law School
The Role of Synnoetics in Modern Society - Sociology Department
The Relationships between Models and the Phenomena that Are Modelled - Philosophy Department

How can we evaluate the amount of services to be provided by the computer center? Although it is a very difficult task, as it has already been stated, each department and research team should periodically make a study of their expected needs on a short time run, say two or three years, and should keep themselves well informed of the up-to-date advances in the computer field (without dwelling in the pure technical field) in order to make the corrections of their forecasts regularly.

Teaching Machines:

This article of the "San Francisco Chronicle" of last April 14, gives us a slight idea of the possible uses of the computer as a teaching machine.

---

[29] Louis Fein, ibid.

Teaching machines have already been experimented with for a long time now[30]:

> One of the most rapidly developing applications of computer technology to education is the use of computer-based teaching machines. A number of institutions are exploring the potential of the computer for controlling instruction of individual students on the basis of differences in learning rate, background and aptitude. The University of Illinois uses a computer to control a teaching system consisting of slides, TV displays and a student response panel. Answers to questions are transmitted to the computer through a response panel, and the computer judges the answers, indicates whether the student is right or wrong, and selects simpler material if the student commits an error. If this type of research is applied to school systems in general, then education is in for a major renovation.

with main emphasis based on the engineering and statistics courses. But computers can be considered as an invaluable tool in teaching game theory which can be considered as the primary use of computers as teaching machines[31]:

> One of the most important applications to economics education is the development of the management game as an educational tool. The injection of the game into the educational process has stimulated the student's appreciation of the decision-making problem in management.

The advantages provided by those teaching machines are numerous as quoted by an engineering professor[32]:

> A broader base of applied problems will afford an opportunity for students to gain a deeper understanding of the scope of

---

[30]Industrial Securities Committee, Survey and Study of the Computer Field, C.A.A., January, 1963.

[31]A. J. Prelis, The Computer in the University, Computer And The World of The Future, MIT Press, 1962.

[32]J. Staudhammer, Engineering Mathematics Via Computers, AFIPS, Vol. 27, Part 1, Fall, 1965.

> modern engineering. Many more significant problems become vivid demonstrations of principles discussed; ramifications of changes in problem formulation become easily demonstrable, and a wider variety of solutions can be supplied to the student upon which heuristic arguments may be based. It is even possible to explore intuitive approaches to the solution of given problems.

or by a statistics professor in his experiments[33]:

> We have reduced to a minimum the classroom time spent on those routine calculations exercises that often deaden the interest of beginning statistics students. (These are learned by doing simple homework problems.)
>
> In the classroom there is more time, now, for extensive discussion of research in general, and of quantitative empirical research in particular. There is much more time to exemplify these by illustrative discussion of the proposals submitted by the students and by analysis of the finished projects submitted.
>
> Still more importantly, we make it possible for the student to look at more problems more ways. It has been our experience that once students begin to use the program library they will run, say, a half dozen regressions at the same time, trying out different sets of independent variables, trying perhaps different types of equations, and even, at times, attacking the same questions and research projects with several different statistical techniques.
>
> There are peripheral, but nonetheless important, benefits:
>
> 1. Students get started on their research projects much more quickly. There is no long period of hesitation while awaiting confidence in computational skills.

---

[33] R. J. Meyer, The Computer-Tutor and Research Assistant, AFIPS, Vol. 27, Part I, Fall, 1965.

2. Research results can be analyzed with the confidence that the arithmetic is correct.
3. The student gets away from the lack of realism inherent in small, round numbered, statistically "clean" problems. He gets deeply involved in most of the real-life problems of empirical research.
4. It is possible to introduce statistical techniques not usually presented in introductory courses. It is possible to illustrate and use curvilinear regression, multiple regression, covariance analysis, two and three way analysis of variance and partial correlation. And data can be more often checked to see whether it meets the assumptions underlying the techniques used.

In fact one can say that these procedures are still in the experimental stage and that much work has still to be done[34]:

> However, extensive use of modern computers by all instructors of engineering and engineering mathematics can eliminate many time-consuming rote calculations from the class presentations. Such an extensive use of computers requires a careful reevaluation of the structure of engineering education. Many new and unique computer programs need to be developed for each segment of the restructured engineering curriculum. The faculty and students need to understand how to use computers and what to use them for, and they need to be able to access the computer programs during normal classroom study. Computer use during classroom discussion can allow for the exploration of a larger number of problems of a greater degree of sophistication than is possible otherwise.

Referring to our topic we can say that in the beginning of the 1970's <u>the use of computers as teaching machines will be very generalized on the campus</u>. With a time sharing system (which will be detailed in Part II) it will be particularly easy to have several locations with remote consoles where students will be able to converse with

[34] J. Staudhammer, ibid.

a library of computerized-problems programs.

The implementation of such a system will bring big changes in the concept of several educational fields.

****

In this first part we have seen that the concept of Computer Sciences and Services on the university campus in the beginning of the 1970's will be quite different from what they are now.

Unfortunately a lack of data, which is a permanent sore characteristic of all which is connected with the computing situation, has not allowed us to draw statistical trends and forecasts, which would be fairly suitable; we have only outlined the big moves which are expected in the educational fields related to the computers.

What can be expected in the technological fields related to the computer? That is the purpose of Part II of this paper.

PART II: THE TECHNOLOGY AND ITS CONSEQUENCES IN THE BEGINNING OF THE 1970'S

It is hazardous to make predictions concerning the future, especially in a field of computer which has grown so fast and which is pushing forward every day, a field where research is heavily concentrated and where a new discovery can overthrow any kind of stabilization people thought they had reached (the example of the transistor is a good one).*

But if we look at the past we can find some trends in the evolution of the computer-oriented people and in the systems those people had to implement.

A. EVOLUTION OF PEOPLE AND SYSTEMS**

1. The Scientist in The Computer Field

It is hard to say if it is the physicist or the mathematician or the electronics engineer who has been the creator of modern computer. Probably the functions were not well defined and it has been a common effort of several people with mixed orientation. Nevertheless, nowadays we can distinguish five classes of people in the computer sciences:

The Physicist
The Electronics Engineer
The Circuit Designer
The Functional Block Designer
The Computer System Designer

who can be defined as follows:

The Physicist:

The physicist is interested in the pure research. He looks at the

* See pages 20-21. Footnote 27.

** We are indebted to Dr. Jean Yves Leclerc of the ARPA project, for his judicious comments on this section.

properties of the matter and defines laws, functions, constants, etc....which reflect the physical behavior of such and such element in such and such experiment. (For example the behavior of an electron in a magnetic field, the compression laws of gas, etc. ...)

The Electronics Engineer:

From the results of the physicist, and especially from all which can concern the behavior of the electron directly or indirectly, the electronics engineer uses the properties of the elements to create special components as diodes, klystron amplifier, etc... in order to get special effects as high voltage, modulation of frequency, amplification of current, etc.

The Circuit Designer:

The circuit designer takes the components defined and built by the electronician and assembles them in special units in order to make them execute a well defined logical function. (For example, the functions AND, OR, INVERT, etc...)

The Functional Block Designer:

The functional block designer has a more extended role than the circuit designer. He creates more sophisticated devices (Functional blocks) to make them execute particularly complicated function. (For example, an arbitrary BOOLEAN FUNCTION, an ADDER, etc.

The Computer System Designer:

The computer system designer defines the components of the whole system the computer is designed for and implement the computer in this system. (For example, a COMPUTER SYSTEM to track a satellite.)

This partition of computer-oriented people does not provide us with five disjointed classes of people. On the contrary there is a permanent stream of information which flows from the physicist to the computer system designer through the electronics engineer, the circuit designer, the block circuit designer and vice-versa; discoveries by the physicist have a straight impact on the job of the computer system designer and the computer system designer tackles the physicist to make him discover more and more interesting properties of the matter. (At least that is the way the things should be).

It can be said that these five categories will be reduced to three in the future:

The Physicist:

will remain the same, interested in pure research.

The Component Designer:

will group the electronics engineer, the circuit designer, the functional block designer, the functions of each of these categories of people becoming very tied.

The System Designer:

will remain the same, but his functions will be defined in a better way than presently, although his involvement will increase more than the involvement of the physicist and the component designer.

The communication feed-back between those people will be very important, and, on it, will rely the efficiency of the whole function: The Design And The Implementation of Computer Systems. From the work of these computer-oriented people it can be expected that:

- The basic quantum of computing time will be in the order of the nanosecond.
- The price of the element will not be the price of the logical unit but the price of the CHIP. (For example 100 functional units per chip will have the same price than 1 functional unit per chip).
- Therefore the hardware components will become cheap; a strong standardization will be necessary: people will buy monolithic arrays, for example one will buy one ADDER one MULTIPLIER, etc...

This evolution of the technology will have an impact on the traditional costs of the hardware and the software whose imputation can be guessed as the following:

60–75%: Software

40–25%: Hardware

The allocation of the costs in hardware will be:

20–30%: Central units

20–30%: Mass storage device

60–50%: Communication systems

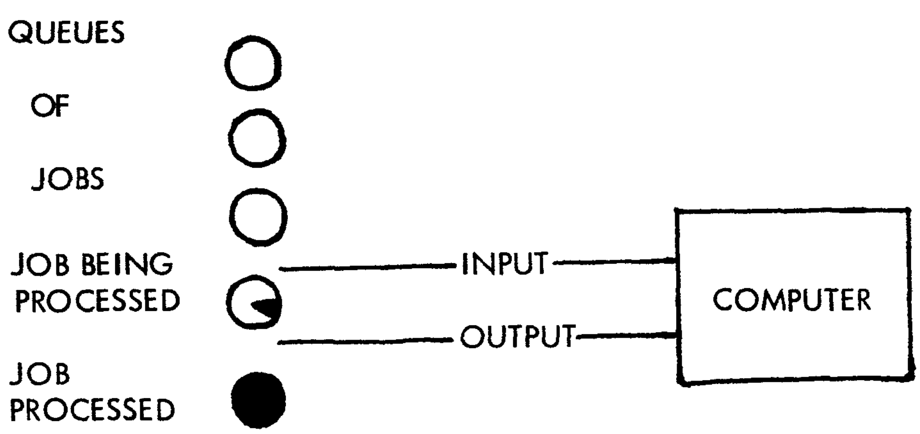
Two important points are well to be pointed out here: first the cost of software is the major cost, and especially the costs of communications are the main part of the cost of Hardware. If we compare to what we have now this is a big difference, where does it come from? Let us look at this question in the evolution of the systems.

II The Evolution of the Concept of Computer System - The Notion of Time-Sharing

At the beginning the computer has been considered as a unique system whose main component was the ARITHMETIC UNIT and whose main tasks were ARITHMETIC COMPUTATIONS. The next step has been the concept of INFORMATION PROCESSOR through one or several CHANNELS OF INPUT-OUTPUT, which made people converse more directly with the computer. Finally a stage which is now in implementation is the notion of informbtion data processing in the extended and elaborated concept of COMMUNICATION AND PROCESSING OF INFORMATION.

In each of these phases, the complexity, the capacity and the power of the computer systems have developed intensively. Some simplified schemes will help in understanding this question:

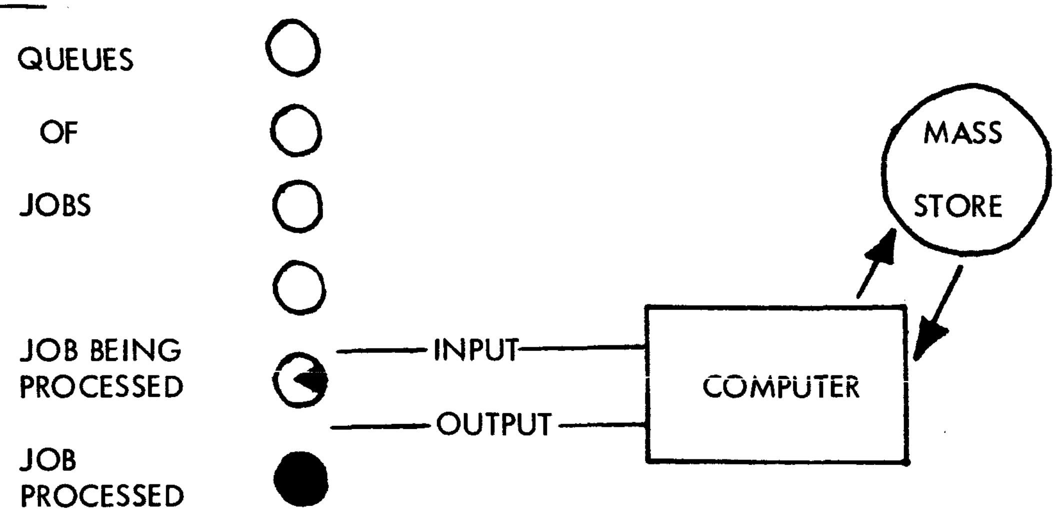
1st Step: CLASSICAL BATCH PROCESSING:



The jobs are in the stack waiting to be run. Each one is run until completion. Usually the Input/Output (cards readers, printer and card punch) is limited.

This system has a lot of inconveniences; big losses of time, important queues, very slow turnaround time, whole program to be punched, etc....

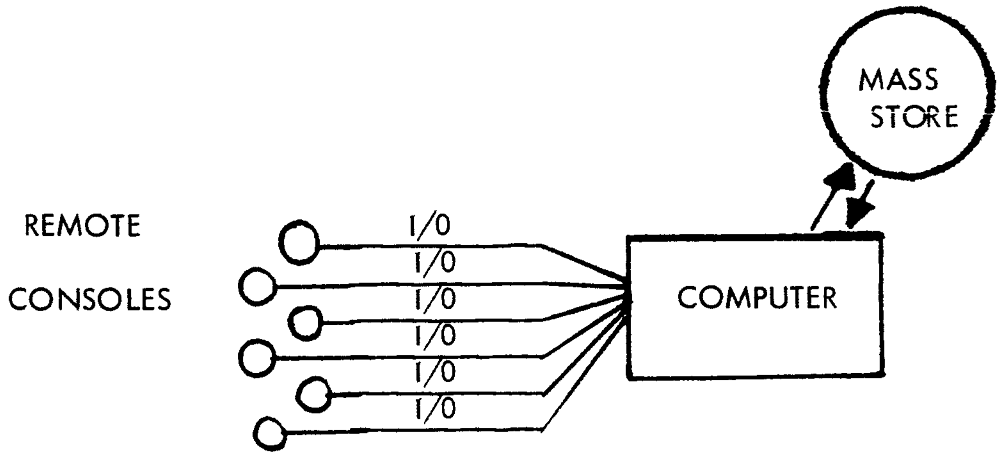
2nd Step: IMPROVED BATCH PROCESSING:



The computer runs programs which are kept on central unit. It is a generalization of the notion of library of all the programs of all the users: the information is kept on a mass store instead of cards. Only orders and modifications are punched on cards for every job.

Besides the information-communication device nothing is changed referring to Step 1, it is still batch processing.

3rd Step: REMOTE BATCH PROCESSING:

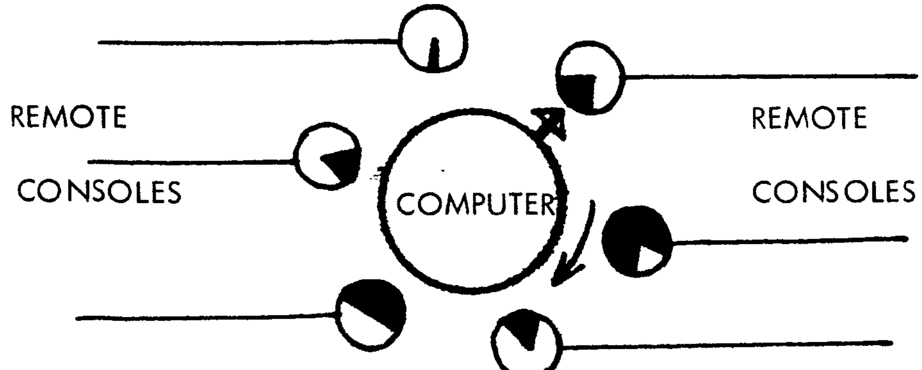


It is still batch processing, but instead of entering the jobs through Input/Output devices the jobs enter through many remote slow and cheap consoles.

ADVANTAGES: Direct entry in the computer instead of first handling the cards deck to an operator. No need for normally sorting the job deck after the run. No need for sorting printer listing. Each console has its own listing. Elimination of more manual operator intervention.

DRAWBACK: Still classical batch processing. High prices of consoles and communication systems if the consoles are far from the campus.

4th Step: ON LINE INTERACTIVE COMPUTING



The computer runs a job for a certain amount of time and then shifts to the next one. Once a job is processed it is automatically removed and another new job to be processed comes in. The time spent by the computer is commanded by the degree of priority of the job.

Communication and storage are the same as in the step before (centralized storage and remote communication) but there is more flexibility in the information processing because the user has the power of dynamically influencing the run of the job. To make this feasible the jobs are intermixed. Most jobs are not run until completion, hence the name of TIME SHARING.

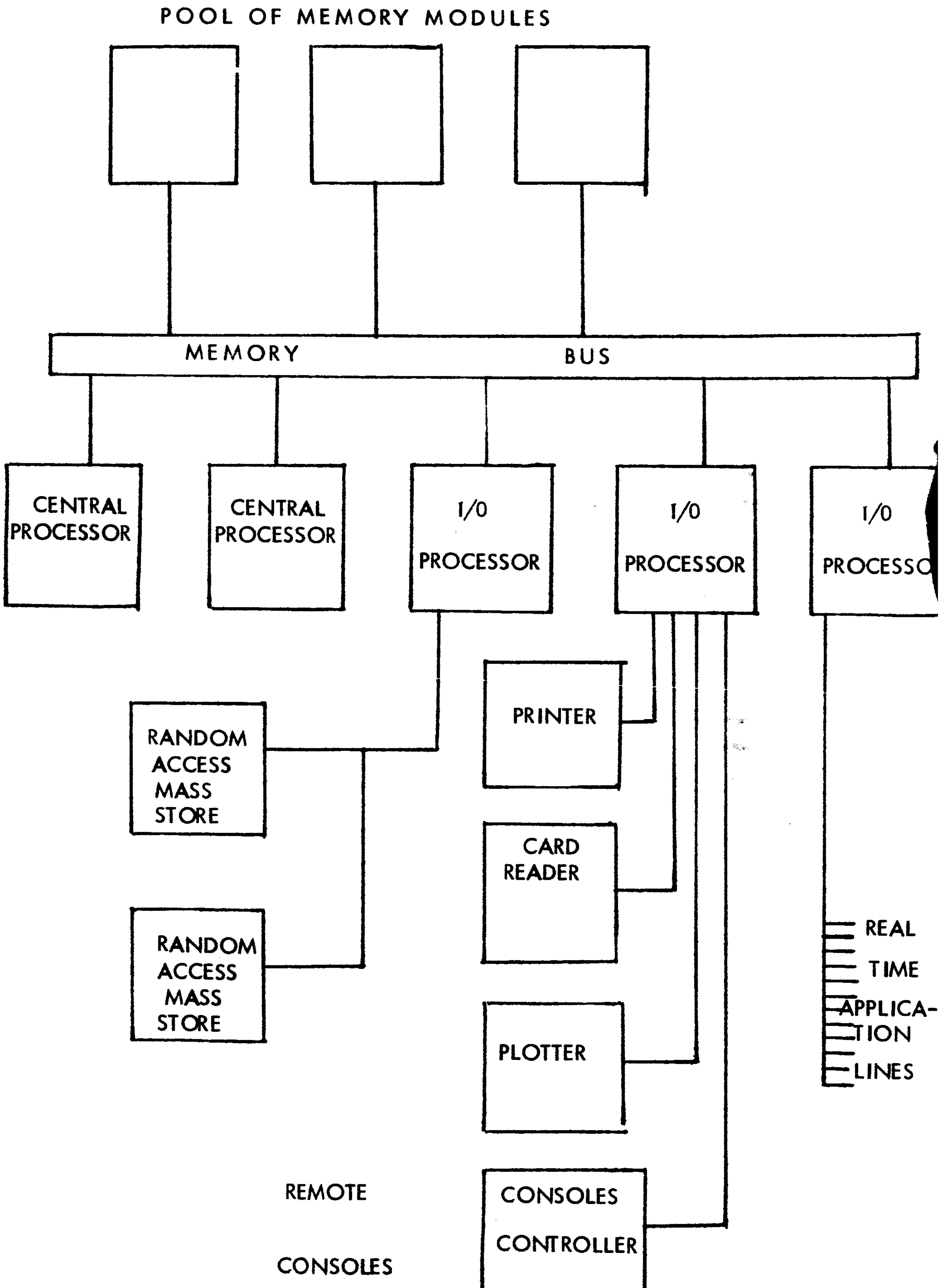
****

We can describe a more sophisticated model:

A system is composed of a pool of memory modules. Certain number of processors share these modules through a memory bus and have direct communication themselves. These processors can be centralized for arithmetic operations for example, or Input/Output processors serving wide variety of Input/Output devices:

> Random access mass store for the centralized storage of the programs and files,
>
> The different consoles and communication lines,
>
> Communication lines for real time application each having a different interphase with the system,
>
> etc.....

This is the final stage reached presently by the computer designers in the concept


POOL OF MEMORY MODULES
MEMORY
BUS
CENTRAL PROCESSOR
CENTRAL PROCESSOR
I/O PROCESSOR
I/O PROCESSOR
I/O PROCESSO
RANDOM ACCESS MASS STORE
RANDOM ACCESS MASS STORE
PRINTER
CARD READER
PLOTTER
CONSOLES CONTROLLER
REMOTE CONSOLES
REAL TIME APPLICA-TION LINES

of the most efficient and reliable computer system. Although this system has raised a lot of controversy[35] and can be considered as being yet in its experimental stage (Project M.A.C. at M.I.T.; A.R.P.A. Project at Berkeley are the leading experiments among the university research teams), it is already implemented by companies and it is not temerarious to forecast that the time sharing system will be the most widely used system in the beginning of the 1970's.

This needs some further development.

B. TIME SHARING: TERMINOLOGY AND PROSPECTIVE

I. Terminology[36]

Although their following meaning has been implicitly defined in the preceding description of the time sharing system, we give here a more formal definition of some of the numerous terms used by the time sharing people:

MULTIPROGRAMMING,

several independent, but perhaps related, programs or routine concurrently residing and operating in an interleaved manner within a computer system.

---

[36] Art Rosenberg, Time-sharing; A Status Report, Datamation, February, 1966.
R. A. Colila, Time-sharing And Multiprocessing Terminology, Datamation, March, 1966.
E. Fredkin, The Time Sharing of Computers, C.A.A., November, 1963.
Special issue of Data Processing Magazine, September, 1965.
Art Rosenberg, Interface 5, a publication of S.D.S.

[35] Neil Macdonald, A Time Shared Computer System. The Disadvantages, C.A.A., September, 1965.

MULTIPROCESSING,
several program processes executing simultaneously within a computer configuration consisting of two or more (hardware) processing elements.

REAL-TIME PROCESSING,
program execution to satisfy a particular operational response time, which may range from the micro-second to the seconds or minutes.

INTERACTIVE OR ON-LINE PROCESSING,
human user or device serviced by a computer system through direct communication with an operating program. For human user, this includes "conversational" interaction.

REMOTE PROCESSING,
user input/output devices are connected by communication facilities to a remotely-located computer system.

MULTIPLE-ACCESS,
a number of on-line communication channels provide concurrent access to a common computer system.

PROCESSOR,
a device capable of performing a set of instructions serially.

JOB DIVIDING,
the task of dividing a job into a number of parts, some of which can or have to be performed simultaneously, but some of which require the completion of other parts before they can be executed.

DIVIDED JOB PROCESSING,
the tasks of programming one or more processors to permit the execution of divided jobs.

PROGRAM SUSPENDING,
the task of determining when transfer of control should take place in a multiprogramming system.

SCHEDULING,
the task of determining what the succession of programs should be in a multiprogramming system.

To facilitate classification of operational responsiveness required by users and their programs, three gross levels can be specified:

PRODUCTION,

Task input prespecified; no user interaction required during execution; turnaround time not normally critical, may be minutes, hours, days.

INTERACTIVE,

On-line task; user inputs dynamically provided during run time; response time of approximately 2-5 seconds for conversation mode, can be longer for variable computing or retrieval tasks.

CRITICAL REAL-TIME,

On line device serviced by task process; strict time-dependency with response requirements ranging from micro-second to minutes. High priority operation which may require special program privileges and resources.

The time sharing system being well defined, what is its prospective?

II Prospective of Time Sharing:

> "However, the ultimate future of time sharing will rest upon economic justification. Non-economic value will quickly fall to zero if economic justification is not soon forthcoming. Trend to closed shop rather than open shop operation in many companies and government organization suggests that individual user needs and desire for computation is not sufficient to justify immediate access."

This conclusion of an article[37] gives us a good idea of the future of time sharing about which people can be said to be "cautiously optimistic" although a lot of advantages are provided by

[37] D. F. Blumberg, Time Sharing: Some Comments and Predictions, D.P.M. September, 1965.

this system:[38]

> "The non-economic values are varied and particularly important to the research scientist, experimentator, programmer and others higher ranks in the information technology field. These non-economic values include:
>
> The feeling of power,
>
> entry into the time sharing system offers the knowledge that a vast computational system will respond instantly to one's needs.
>
> Prestige,
>
> in the present state of development those with consoles and/or appropriate entry numbers have a decided advantage over their less fortunate peers.
>
> Humor And Entertainment,
>
> the existence of a tic-tac-toe, two sided blackjack and other games in which the computer acts as a participant, can offer to the bored or jaded user some degree of humor and entertainment during the long working day.
>
> A Research Vehicle,
>
> an important non-economic value is the ease of availability of computer time to the researcher particularly in the computer sciences. The researcher would like to gain access to the computer, over short periods of time with little delay in order to solve a specific problem or to verify an intuitively derived idea.
>
> Program Checkout And Debugging,
>
> an extremely important value of time sharing is that it allows the programmer quickly and efficiently to debug and check out programs which have been recently written.
>
> Simulation And Behavorial Sciences Experiments,
>
> time sharing system can be extremely valuable in studying man-machine interaction, communication and decision processes; particularly in behavioral and open-minded simulations in which man plays a dynamic role.
>
> Information Searching And Retrieval,
>
> a time shared system offers an interesting capability for obtaining answers and extracting information from a large storage of files through browsing in real time."

---

[38] *Ibid.*

But on the other hand, it is to be emphasized that universities and companies are still debugging the implementation of time sharing and some <u>disadvantages</u> can be listed:[39]

> "A number of reasons can cause a time-shared computer system to stop running. They include: scheduled maintenance; finding and repairing failures; adding or subtracting peripheral units; modification of the monitor programming that does the time sharing, etc.....
>
> Another disadvantage to the time shared computer system is that there is continual pressure for access to the system. For example, at a university, more and more of the faculty and the students will want access, and are likely to receive permission to use the system....
>
> As a result of pressure for access to the time-shared system, it is likely that a system of priority will be set up. Then some persons with high priorities can get all the time that they want (whenever they want it); less favored persons get less; and the low man on the totem pole has to use a console from 2 to 5 in the morning in order to get access without undue waiting.....
>
> A person who uses time-shared system is at the mercy of the supervising and monitoring system. It is bad enough to be at the mercy of a human being who supervises a computer room and who is in charge of scheduling work for the computer, and who can put your problem on the computer when he chooses to....
>
> The knowledge of how to use a time-shared system is likely to expand voluminously and to be recorded in a tremendous file of memoranda. Yet information in that file of memoranda is likely to become harder and harder to dig out. At least two causes operate to make this happen.
>
> First, a time-shared computer system implies 20 or more very bright people working on the different parts of the system and developing it. These people with their fast minds are unlikely to be good at explaining on paper to slower minds

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[39] Neil Macdonald, *ibid*.

what they are doing. Consequently the slower minds (or the minds who were fast ten years ago, have now risen in the economic scale, and who have other duties to attend to) find it harder and harder to keep up. Eventually each user will only use a small part of the mass of the software technique in the time-shared system.

Second, a time-shared computer system is likely to be one of a kind. In contrast, for the usual computer which is sold in ten or hundreds of copies, there is a strong pressure from the market of user to simplify and unify the hardware, so that it can be applied to each kind of computer. No such pressure exists for a one-of-a-kind time-shared computer system. As a result its software will cost more, be more complex and be less used.

Finally the cost of computing power is steadily dropping. So it seems likely that soon more people can have more computing power for less cost by avoiding the unnecessary troubles of a time-shared system, and solving a great part of their need for computer power with a small computer. In much the same way, some families solve almost all of their problems about the time sharing of a car, when both husband and wife have a car each.

Furthermore it seems likely that 90 or 98 percent ~~of the~~ problems that most individuals would like to have a computer for, could be done on a small computer, with, say, a disc memory, for less cost than the appropriate part of the hardware and software of a time-shared system."

and measurements made of time-shared system performance and users characteristics are just beginning to be published by university people.[40] (Undoubtedly the leading manufacturers of computers have conducted many a study on the time-shared systems but they keep them carefully secret).

Hence the pioneer work is a formidable task in such a complicated field as the time-shared systems. The problems areas associated with time-sharing implementation

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[40] A. L. Scherr, Time-Sharing Measurement, Datamation, April, 1966.
A. L. Scherr, An Analysis of Time-Shared Computer System, The MIT Press, Cambridge (in press)

can be placed in three categories:[41]

1. Technical (Hardware and software)
2. Sociological (organizational and administrative)
3. Economics

1. Technical:

The technical problems can be classified in three main categories:

For Hardware: dynamic relocability, fragmentation, list processing, swapping overhead etc...

For Software: parametrization, "idiot-proofing," handling all applicable cases, indirect referencing of context data, separation of process from user context, process reentry, etc....

Communications: the communications problems will be the most important ones in time-shared systems:[42]

"However, the subject of communications is currently a sore point with time-sharing enthusiasts. This is true, not necessarily because communications technology is inadequate to service remote on-line users, but because the mundane aspects of costs and communication services has not yet been mated to the lofty concepts of remote on-line time-sharing.

The problem breaks down in three main areas: terminal equipment, service, and transmission costs."

2. Sociological Problems:

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[41] Art Rosenberg, _ibid._

[42] Art Rosenberg, _ibid._

Page 40 and 41 in Neil Macdonald's article, we have already evoked some of these problems. In the same way that it can be said (*) that less of the problems of NASA are technical and consequently the complement part are sociological and managerial problems, we think that it is not too presumptuous to paraphrase and to say that the biggest part of the problems of a time-sharing system will be sociological and managerial. In the same idea we can quote[43]:

> "Centralization of computer facilities can cause repercussion in a line organization where several independent "shops" existed previously. Line managers or individuals may have to relinquish control over their little computer "empires" and become a mere subscriber to the large system. This fact may merely hurt the ego in some cases, but there may also be a serious feeling that somehow loss of absolute control of a machine will hinder research and experimentation. Certainly any user with his own machine will not be happy if all his programs have to be rewritten or certain special peripheral devices cannot be serviced by a centralized system."...
>
> "Now that more direct computer contact will increase, new problems are arising in the computer's future, "people" problems; this call for programs to be human engineered. Education is vitally necessary to get user message across, both to the programming community and the non-computer people. The programmers must recognize who will be on-line users; the non-computer people must be aware that computers will conveniently serve them and begin to concentrate upon their own application problems. Because innovation and fundamental environment change are involved, the education task will not be an easy one."

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[43]Art Rosenberg, ibid.

*Don Marquis, Seminar Of The Space Sciences Laboratory, Berkeley, March 29.

In those sociological problems, enter the problems of security and protection of each user's file from the other potential users.

3. Economics:

the whole structure of costs has to be settled and nothing has been determined in this field yet. A certain number of factors will be significant to the users and to the management that pays the bills. These factors include:

efficiency
effectiveness
elapsed time
convenience and accessibility
small machine versus a large machine configuration
initial investment
organizational compatability
retraining costs
etc....[44]

****

In this section we have seen that through the evolution of the technology, the computer systems are oriented to a big implementation of time-shared concept. The time sharing systems actually in use are in the experimental stage and a lot of unknowns remain concerning the technical part, mainly the communications problems, but in a more crucial way concerning the sociological and managerial part: studies on management, organization, economics of time sharing systems do not exist yet and have hardly been started to be published.*

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[44] Marvin Emerson, The "Small" computer Versus Time-Shared Systems, C.A.A. September, 1965.

W. W. Finke, Computers and Economic Concentration, C.A.A., December, 1965.

V. Genzlinger, On Line Real Time vs. Time Sharing, D.P.M., March, 1965.

*See footnote 40, p. 41.

Therefore extended research concerning those points has to be undertaken in order to clear the way to use a time sharing computer system with the optimal efficiency. This is not an easy task; how will a university deal with the situation? That is what is developed in the next part of this paper.

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PART III: MAPPING THE CONCEPT OF A UNIVERSITY COMPUTER CENTER IN THE TECHNOLOGY OF THE BEGINNING OF THE 1960'S

The concept of a university computer center in the beginning of the 1970's, is the symbiosis between the task of this university computer center and the technology and its consequences at that time. Therefore the writing of this section should come directly from what has previously been written.

In fact our survey of these two points has raised more unknowns, more guesses than it has brought accurate definitions of the problems involved. We would jeopardize a lot by claiming that the events will behave in such and such way when we have no proof for handling them and it would not be difficult for people to put us into trouble and to have serious doubt about the value of this study.

Therefore, our claim will be more to define the methodology to be used in further extended studies that have to be undertaken to bring a definite solution to the problem, than to give this solution. To do that in:

A: THE UNIVERSITY COMPUTER CENTER IN THE BEGINNING OF THE 1970'S: THE TIME SHARING SYSTEM;

We will shortly justify the system that, as we think, will be in use on the campus of the university at that time. Then in

B. METHODOLOGICAL RECOMMENDATIONS FOR A BETTER KNOWLEDGE OF THE PRESENT SITUATION AND AN EFFICIENT IMPLEMENTATION OF THE FUTURE SYSTEM;

we will analyze the main results of the study done in this paper and from these results we will make recommendations for improving the present and future computing situation on the campus.

A: THE UNIVERSITY COMPUTER CENTER IN THE BEGINNING OF THE 1970'S: THE TIME SHARING SYSTEM.

a. From the opinion of experts in the computer field:[45]

> "I don't think individual departments should have separate facilities. This will cause one department to tend not to profit from other's experience.
>
> Remote consoles are the answers if they can be afforded financially. It is a marvelous idea but strictly a matter of economics: Costs for the remote facilities vs. the cost to go to the central computer.
>
> I have watched steadily and so far the economic break has always been: if you have so much money, put it in the biggest computer because it is cheaper per operation than small computers...Maybe the economics may shift in the future but up to the point we have always found it cheaper ... more computing per effort spent...to put it all in the biggest computer you can afford rather than to spread it out over several small ones."
>
> Haming

> "Departments will have their problems determined by the size of their machines...They will tend to think small with small machines."
>
> Perlis

> "Professor Perlis also said that it must be employed simultaneously by several users at remote stations. Let me amplify that requirement by saying that each user must be able to work on his own problem, at any time, as though he had a slower machine with almost as large a memory.
>
> He must be able to use his own programs and, in addition, the very large addition of compilers, interpreters, utility programs, tables, and data stored permanently in the central computer. With the aid of compilers and interpreters he must be able to interact with the computer in a way that is reasonably natural to the human scholar. In any event, he must not have so to clutter his mind with codes and formats that he cannot think about his substantive problem."
>
> Licklider

> "If all the complex requirements of university work are to be handled

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[45] Conference Report On The Use Of Computers in Engineering Classroom Instruction, A.C.M., 1960, p. 522.

The Computer In The University, Computers And The World Of The Future, MIT Press, 1962.

R. A. Buckingham, The Computer In The University, C.J., April, 1965.

successfully in the future it is almost axiomatic that it must be possible for a central computer or computer system to be used simultaneously by a large number of users, many of whom may be remotely located. It is easy to devise such a system but a great deal of research has yet to go into the design of hardware, the logic of the systems, and especially into the software which will control the flow of work and enable programs and data to be relocated at will within the system. I believe that with the present trend in computer development a system can be developed to meet very diverse requirements with a substantial degree of efficiency, reliability and accuracy. At least it should be clear to every one that the computer revolution has hardly begun.

Buckingham

b. From the survey which has been done in this paper (see Part II of this paper, p. 27-44).

c. From the ideal characteristics of a university computer center which are:

1.
   - 1A: Good Batch Processing
   - 1B: Remote Batch Processing

2. Interactive Computing

3. Real Time Data Collection

it clearly appears to the author that:

THE BEST SYSTEM FOR A UNIVERSITY COMPUTER CENTER IS THE TIME SHARING SYSTEM AND THAT THIS SYSTEM WILL BE FULLY IMPLEMENTED IN THE BEGINNING OF THE 1960'S.

B: METHODOLOGICAL RECOMMENDATIONS FOR A BETTER KNOWLEDGE OF THE PRESENT SITUATION AND AN EFFICIENT IMPLEMENTATION OF THE FUTURE SYSTEM.

In the preceeding section: "A: The University Computer Center In The Beginning Of The 1970's," from consideration involving: the opinion of experts, the study done in this paper, the ideal characteristics of a university computer center, we have postulated that the time sharing system will be the most efficient computer system for university people in four or five years from now.

Implementing such a system will not be an easy task. Two main reasons occur to the author of this paper:

1. On one hand, a university computer center is a system, the components of which are very complicated: big investments, big operation costs, big variety of jobs, diversified users with different tasks, etc. Precisely from the intricate complexity and mixing of the components of such a system, direct shifting from an old system to a new one cannot be done on the spot: the elasticity of the material and human structures is very small and the change must be performed in harmony with the policy of the management.
2. On the other hand the new computer system which is involved, the time sharing system, is still in the experimental stage. Numerous unknowns, technical, economical, managerial remain and those unknowns have to be cleared for the implementation of the time sharing system.

On one hand we have the "present policy," or the needs for a better understanding of the present situation; on the other hand, we have the "new system" or the need for a better understanding of the future situation.

1. The Computing Policy Or The Needs For a Better Understanding Of the Present Situation.

a. Need Of a Statistical Bureau.

In section A of part 1 "Analysis Of The Present Situation,"* the author has defined which parameters should be analyzed rather than in fact studying them.

The reason for that is very clear: the only good information which has been available to him is the survey done by the Survey Research Center ** (in 1962) and the scarce statistical data picked here and there are inconsistent for valuable comments or assertions.

The work done by the two committees, the Chancellor Advisory Committee on Computing Facilities and the Computer Center Advisory Committee, have not been available to the author who experienced frustration in front of the impossibility of conducting a good statistical analysis of the computing situation.

At the beginning of this study, from collection and reduction of data, it was intended to plot the graphs over years of some descriptive parameters of the computing situation (as examples: evolution of the categories of users and non-users ...evolution of the size, the frequency of the jobs...evolution of turnaround time, of idle time, lost time...financial analysis of budgets over time...etc...) in order:

-to get sound notions of the evolution of the computing situation

-to determine the environment of the computer center

-to detect the trends, if any, of the present situation ***

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* See page 1-8.

** See footnote 8, p. 4.

***It has often been pointed out to the author that the technology is evolving so fast that such an attempt would be useless. If no attempt at all has been done up until now (and we have not found any trace) we do not see how some people can justify their assertions, even if systems as computing systems have an extraordinary level of complexity. We think that such feelings have been a common error from the majority of scientific people each time the implementation of a big discovery has taken place in physical sciences (microscope, electronic field etc...)

Referring to the present situation this task could not be conducted. Although this task will not be an easy one, the author believes that without good collection and reduction of data, followed by statistical inference done periodically (in the same way as statistical inference illustrated by graphs is done at regular times in factories or company management) it is particularly difficult for the management of the computer center to grasp the complexity of the situation and to visualize the technical, economical, managerial problems.

The work of some further research team of statisticians, or economists, or analysts, who are interested in elaborating efficiency criteria, guidance rules, management theory etc...for the computer center management, will be impossible without this data.

Recommendation 1:

> PRESENT BODY SHOULD BE REVIEWED TO DETERMINE WHERE THERE IS AN ADEQUATE HISTORICAL RECORD WHICH SHOWS THE COMPOSITION OF THE DESCRIPTIVE PARAMETERS OF THE COMPUTING SITUATION. A STATISTICAL BUREAU SHOULD BE CREATED IN ORDER TO RECORD ALL THE DATA DEALING WITH COMPUTING ON THE CAMPUS.

b1. Better Knowledge of the Concept of Teaching and Research.

In section B of part 1, "What The Future Will Be," the concept of teaching and research in computer sciences has been investigated.* In a historical summary we

*See pages 8-18.

have seen how this concept has emerged from the vague ideas that computer people had of computing sciences not later than six years ago. This trend of asserting fully the entity of computing sciences, is irreversible and one can say that the demand will increase considerably in this new field in the future.

Therefore, in order to provide a sufficient supply to the demand without too many difficulties, studies have to be undertaken in order to strengthen the present estimates.

It has often been pointed out to the author that, in this area too, trying to forecast the demand is to jeopardize a lot (especially with a future system as time sharing which will offer considerably improved facilities to the user and hence it is difficult, and probably impossible, to forecast good estimates at the present time. Nevertheless it is best to begin <u>to think</u> about this future demand: the elaboration of a set of estimates (The demand will increase by 50 percent or 100 percent or 200 percent or 500 percent . . . in three or four or five years . . .) will not find the management unaware when such a given rate of increase takes place: having already thought about such an event in preliminary studies it will be relatively easy for this management to handle a situation in which a lot of unknowns will have been analyzed.

<u>Recommendation 2:</u>

> IT IS NECESSARY TO UNDERTAKE THE "THINKING" OF THE ESTIMATION OF FUTURE DEMAND OF THE CONCEPTS OF TEACHING AND RESEARCH IN COMPUTER SCIENCES. THIS

TASK SHOULD BE DONE BY A RESEARCH TEAM SETTLED FOR THIS PURPOSE, HELPED BY THE WORK ALREADY PERFORMED IN THIS FIELD* AND FOLLOWING THE NEW CONCEPT OF EDUCATION TO BE GIVEN ON THE BERKELEY CAMPUS.[46]

b2. Better Understanding of the Needs of Industry.

Besides the demand of teaching and research in computing sciences, the academic people in the computer field have to be aware of the crucial needs of computer people by the industry for the year 1970 **. To satisfy these needs it is not impossible that some intensive training program could be set up on the campus.

Recommendation 2a:

A RESEARCH TEAM SHOULD BE SETTLED TO STUDY THE NEEDS OF INDUSTRY FOR COMPUTER PEOPLE AND TO EXAMINE IF IT IS NOT POSSIBLE TO GIVE ACCELERATED PROGRAMMING COURSES CONCENTRATED IN A SHORT PERIOD OF TIME IN ORDER TO HELP SATISFY THESE NEEDS.

*See references 22, 23 (page 14) and appendix especially.

** See pages 8 and 9.

[46]"The notion of supervicially 'surveying' a traditional subject matter must be baandoned. Instead, the best intellectual on the campus must be attracted to courses which can be devoted to fundamental intellectual principles and topics, or to the chance to demonstrate the application of research to problems of special interest.", Education At Berkeley Report Of The Select Committee on Education, University of California, March, 1966, p. 126.

c. Better Knowledge of the Concept of Services.

In section 2 of part 1: "Services"* we have elaborated on the role of computer as device and tool. Referring to these uses of a computer as device and tool no statistical data, no descriptive parameters, no normative criteria have been available to the author. (Besides the survey done by the Survey Research Center already mentioned).

The author believes that the uses of computer facilities by people in Business Administration are different from the uses by people in Biochemistry, that the criteria of computing efficiency for people in Electrical Engineering are not the same as the criteria of people in Humanities, that the implementation of teaching machines on the campus will bring drastic changes in the concept of services which are provided to the university community, etc....therefore, the analysis of the allocation of services, the studies of their trends, their forecasts, their dynamics, etc....would considerably improve the understanding of the computing situation.

Recommendation 3:

A RESEARCH TEAM SHOULD BE FORMED TO ANALYZE THE KINDS OF SERVICES WHICH ARE AND CAN BE PROVIDED BY THE COMPUTER CENTER. ITS ROLE SHOULD BE A DYNAMIC ONE PROVIDING BETTER KNOWLEDGE AND BETTER ESTIMATES OF THE PRESENT AND THE FUTURE EVALUATIONS OF SERVICES WHICH ARE PROVIDED BY THE COMPUTER CENTER.

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*See pages 18-26.

These four recommendations:

a. Need of a statistical bureau

b1. Better knowledge of the concept of Teaching and Research

b2. Better understanding of the needs of industry

c. Better knowledge of the concept of services,

have focused the ideas of providing a better understanding of the computing situation. Their predictive role in the evaluation of the various demands (Teaching and Research, Services) has been emphasized. This leads us to look at the future system which will satisfy these demands.

2. The New Predicted System Or the Needs For a Better Understanding of the Future Situation.

In section II: "Evolution of the Concept of Computer Systems, The Notion of Time Sharing System" * we have described the main technological features of the components of a time sharing system. In the section B: "Time Sharing: Terminology and Prospective" ** we have given a definition of some of the numerous terms used by the time sharing people and we have provided a listing of some advantages *** and disadvantages **** of the system involved.

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* See pages 31-36.

**See pages 36-44.

***See page 39.

****See pages 40-41.

The problems of the implementation can be classif[illegible] three [illegible]

technical, economical, sociological.

a. The Technical Problems *****

Hardware, software, communication[illegible]

the three milestones of the technical problems, the studies of which in[illegible]

a lot of tedious and highly complicated work.

How will the management of the future time sharing system be [illegible]

overcome these technical problems?

Recommendation 4:

IN THE PERSPECTIVE OF IMPLEMENTING THE TIME SHARING

SYSTEM ON THE BERKELEY CAMPUS A RESEARCH TEAM

SHOULD BE SETTLED TO STUDY THE PROBLEMS OF HARDWARE

SOFTWARE, COMMUNICATIONS NOT LIMITED AT THE EX-

PERIMENTAL STAGE, AS IT IS PRESENTLY DON[illegible]

SCALE OF THE WHOLE CAMPUS COMMUNITY.

b. The Economical Problems *

The implementation of [illegible] time sharing [illegible]

will rely upon economic justification.** Unfortunately the autho[illegible]

been able to find any book or article which brings comments of [illegible]

deal and solve these problems although he has conduc[illegible]

*****See page 42.

* See page 44.

** See page 38.

research *.

Therefore if there is no information available on the economics of the computing situation in general, on which appraisal will the management of the computer center base the implementation of a time sharing system being that the justification relies precisely on economics considerations?

Recommendation 5:

AS UP TILL NOW NO ECONOMICS STUDIES HAVE BEEN CONDUCTED ON THE COMPUTING SITUATION ON THE BERKELEY CAMPUS AND AS THE IMPLEMENTATION OF THE TIME SHARING WILL RELY ON ECONOMIC JUSTIFICATION A RESEARCH TEAM SHOULD BE SETTLED TO DEFINE THOSE ECONOMIC PROBLEMS AND TO STUDY THEM. THE ANALYSIS OF COSTS, THE METHODS OF FINANCING AND BUDGETING SHOULD DEMAND SPECIAL ATTENTION.

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*The author has not been able to get the book: "Economics of Automatic Data Processing," Proceedings of the International Symposium on Economics of Automatic Data Processing, Rome, October 19-22, 1965, edited by A. B. Frielink, published by North Holland Publishing Co., Amsterdam, 1965, 384pp.

It seems to the author that, besides the bibliography mentioned in this paper(and which is the only bibliography which was available to him in Berkeley compus libraries), these proceedings represent the only and the first publication of value on economics of EDP.

The computer manufacturers must have conducted extended studies on this field, but, as they perfectly know that the management of EDP departments in companies reaches a very low rate of efficiency (referring to what it should be) their policy is to let the things go on this way, and...to sell more hardware, software, equipment etc...: it is better for car manufacturers to have as customers very bad drivers who mishandle the engine than to deal with people who know how to drive a car.

c. Sociological Problems *

A time sharing system is a system which will require people to think and to run computing in a different way from the classical batch processing to which they are accustomed.

Some people who will get a feeling of power at their consoles, who will run their problems without constraints of walking to the computer center and liberated of the tutorship of an "uncomprehensive" management etc... will enjoy it very much. Other people losing the power of their little computer "empire," afraid of being lost in a huge system, or fearing to be maintained at a low degree of priority which will offer them the use of the computer in the middle of the night etc....will dislike the idea of a time sharing system.

To educate these people, to teach them the purposes of the time sharing system, to demonstrate for them the advantages, the improvement provided referring to the old system, to train them to run this new system, to avoid stepping on the toes of the more sensitive people, etc...are the components of a task which will not be easy and which will require a long period of time.

Recommendation 6:

A RESEARCH TEAM SHOULD BE SETTLED TO STUDY THE SOCIOLOG-ICAL IMPACTS OF THE IMPLEMENTATION OF TIME SHARING SYSTEM. AS THE EDUCATION TASK WILL NOT BE AN EASY

*See pages 42-44.

ONE AND WILL REQUIRE A LONG PERIOD OF TIME IT IS RECOMMENDED TO MAKE PEOPLE FAMILIAR WITH THE NOTIONS OF TIME SHARING AS SOON AS POSSIBLE AND TO DEFINE TRAINING PROGRAMS WHICH WILL BE IMPLEMENTED PROGRESSIVELY.

d. Period of Transition.

It has already been mentioned that a university computing system is a large system which cannot be replaced by a new one on the spot: one does not change the hardware and the software of a computer system as one replaces an old car with a new model with higher performance. The transition time will especially require a tedious and extensive work of reprogrammation and training people for several years.

Recommendation 7:

THE OLD SYSTEM SHOULD BE KEPT RUNNING FOR A FEW YEARS CONCURRENTLY WITH THE TIME SHARING SYSTEM, THE LATTER'S IMPORTANCE STEADILY INCREASING. THE OLD SYSTEM SHOULD STAY ON THE BASIS OF ITS RELIABILITY UP TO THE TIME WHEN THE TIME SHARING SYSTEM REACHES A BIG ENOUGH PERCENTAGE OF THE TOTAL COMPUTING WORK DONE ON THE CAMPUS TO BE JUDGED PERFECTLY RELIABLE.

THE PROBLEMS INVOLVED DURING THIS PERIOD OF TRANSITION DEALING WITH THE CHANGE PROCEDURE SHOULD BE STUDIED BY A RESEARCH TEAM.

* * * * * *

The preceeding recommendations are focused on two ideas:

- The improvement of the knowledge of the computing situation by settling research teams in charge of studying such and such features about which people do not know very much at the present time,

- The preparation of an efficient implementation of a time sharing system with the help of preventive studies.

But a doubt remains: how can the management know that the answers, the predictions of the studies are correct and feasible? How will the management be able to check that people have been looking for what was to be looked at and that people have measured what was to be measured?

Final Recommendation:

THE AUTHOR RECOMMENDS THE ELABORATION OF SIMULATION MODELS OF THE COMPUTING SITUATION ON THE CAMPUS. THE SIZE OF THESE SIMULATION MODELS WILL BE DETERMINED BY EXPERTS IN THIS FIELD. THESE SIMULATION MODELS WILL BRING A LOT OF INFORMATION TO THE MANAGEMENT OF THE COMPUTER CENTER AND WILL BE VERY EFFICIENT GUIDES IN THE APPRECIATION OF A SITUATION WHICH IS NOT EASILY HANDLED.*

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*It has often been pointed out to the author that a university computing system is too large and too complicated a system for simulation studies. To dissipate the skepticism of the people, the author recommends the reading of G. K. Hutchinson: "A Computer Center Simulation Project," work supported in varying degrees by Lockheed Missiles And Space Company, Stanford University Computation Center, and the Western Data Processing Center.

CONCLUSION

The study done in this paper does not bring a positive answer to the definition of the concept of a university computer center in the beginning of the 1970's, but merely emphasizes the lack of information and the present lack of feasibility of performing a good survey of the problem.

But on the other hand, it is better to know, now, that such and such questions have to be studied, than to deal with a problem the aspect of which being permanently maintained in vagueness and the pitfalls of which having not been defined yet.

We think that this study "An Approach To The Design Of A University Computer Center In The Beginning Of The 1970's" clears the way to a further study: "The Design Of A University Computer Center In The Beginning Of The 1970's" to which it can be considered as an introduction. To conclude we want to give an example of this future computer center and its cost analysis, the technical assistance for this example having been provided by the people of the ARPA project.

SYSTEM:

The system is a time sharing system connected by telephone lines to different terminals.

SERVICES GIVEN:

We assume that there are 30,000 people to be served, each user requiring an average of 1/2 hour at a console per day. The system is working 15 hours a day. This means the system has to provide 15,000 hours to the users per day, so that 1,000 users are working at the same time on the system.

CONSOLES:

If we assume that because the real time experiments require a lot of data, they are connected to the computer system through smaller specialized computers to reduce the band-with, we can assume that most of the terminals will be connected through normal telephone lines. These terminals will be either typewriters or more sophisticated displays. It is not unthinkable that each professor or group of students may have their own consoles which will then be inexpensive. At certain locations on the campus there will be heavily used terminals which have then to be much more reliable and so, probably more expensive. We count an average for consoles of say $500.

CENTRAL COMPUTER:

We have seen that we need to handle an average of 1,000 users at the same time. Let us choose a particular example of a computer as the SDS Sigma 7. The specialists believe that it is possible to put 150-200 users on each processor. We will then probably need 5-6 processors.

We will assume a central memory of 256,000 words; 10 million words of drum will probably be necessary for the fast back memory; big mass store will help storing all the programs of the users. Assuming each user may be able to store 50,000 words, we will then need a capacity of 1.5 billion words which will represent about 8 units of mass store. (50,000 x 30,000 = 1.5 billion)

Extrapolating the prices of the present system we can expect the figures:

5 processors at $100,000 each	$ 500,000
256,000 words memory	1,000,000
10 millions words of drum memory	250,000
8 mass store	1,600,000
miscellaneous	100,000
Total	$ 3,450,000

PROFITABILITY:

Assume we have 2,000 consoles at $500 each including the prices of the

lines and the connections:	1,000,000
Cost of the central computer	3,450,000
The total cost will then	4,450,000
say	$ 5,000,000

Such a system could be in service for at least 5 years, which represents an investment of 1,000,000 dollars per year.

This would give a flexible computing device at the price of $\frac{\$1,000,000}{30,000} = 33$ dollars per user, say less than 40 dollars per user per year.

****

We think that this estimation of the demand, 1/2 hour at the console every day for each of the 30,000 users, largely fits with the expected value of this demand. Hence, besides some considerations for the software, for which a big job has to be done, such a system seems to be a very promising one.

BIBLIOGRAPHY

Table 1: BOOKS

Table 2: SPECIALIZED REVIEWS

Table 3: MISCELLANEOUS

NOTE:

1. The references of Table 2: "SPECIALIZED REVIEWS" have been classified in four categories:

   a. Methodology: Management of computer department; Organization; Investment in computer; Economics; Profitability; Social implications; etc....

   b. Systems: Hardware; Software; Communications; Simulation; Data Transmission; etc....

   c. Time Sharing: Principle; Organization; Terminology; Advantages; Disadvantages; Economics; etc....

   d. University: Organization of a University Computer Center; Computer Sciences; Teaching Machines; Computers and Education; etc....

   It has to be emphasized that this classification is arbitrary; the contents of the majority of the articles have more than one purpose and can be used in several categories.

2. The references of Table 3: "MISCELLANEOUS" have been classified in four categories:

   a. Newspapers and Magazines

   b. Survey

   c. Working Papers

   d. Others

TABLE 1: BOOKS

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